Search for CPV and New Physics at CLEO[1]

Vladimir Savinov (CLEO Collaboration)
School of Physics and Astronomy, University of Pittsburgh
3941 O'Hara St., Pittsburgh PA USA 15260
vps3@pitt.edu, www.phyast.pitt.edu/~savinov

Abstract

Recent CLEO results on the search for CP violation in decays of B and D mesons and τ lepton are reviewed. New data on "wrong-sign" D decays and $B \to K^{(*)}l^+l^-$ FCNC transitions are presented. As possible Standard Model contribution to many of studied processes is tiny, described efforts constitute the search for physics beyond the Standard Model. Future CLEO-c efforts on the subject are outlined.

1 Introduction

The ultimate goal of many current and future efforts in experimental physics of elementary particles is discovering possible new symmetries in Nature. These symmetries, commonly referred to as the "new physics" could realize via previously unknown interactions that we are becoming sensitive to with novel detecting devices at collider-based experiments as the energies available to these machines are growing. Besides academic curiosity about the processes that might be allowed beyond the current energy frontier, there are many important questions that are outside the scope of the Standard Model (SM) of elementary particles. Among these are quantifying the imbalance between matter and antimatter in visible Universe, why there are three generations of quarks and leptons in the SM hierarchy, what is the connection between two fundamental statistics, if quarks and leptons are truly point-like particles and other open problems. Last but not the least, I have to mention that we have not yet obtained the experimental proof of the origin of mass, neither we know if the Coulomb's law holds at very small distances and if there is any connection between gravity and possible extra dimensions.

The results presented in this short review were obtained from the data collected at the Cornell Electron Storage Ring (CESR) with the CLEO series of detectors. These results are based on statistics that correspond to an integrated e^+e^- luminosity of up to 9.2 fb^{-1} collected at the Υ(4S) energy of 10.58 GeV and up to 4.6 fb^{-1} collected approximately 60 MeV below the Υ(4S) energy. These energies are far below the energies available at Tevatron, LEP and future LHC experiments, however, the tiny effects of new physics at such low energies could be amplified by strong interaction that might give rise, for example, to direct CP asymmetry in particular decays of B and D mesons. The measurements described in this review are, most of the time, the limits on how rare the searched-for processes are. Presenting our experimental results in the form of limits on masses, coupling constants and other parameters associated with the new physical processes is highly model-dependent

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and is left outside the scope of this review. Only more recent CLEO efforts are described, while neutrinoless[1] and anomalous radiative[2] τ decays, rare η' decays[3], familon[4], scalar bottom quark[5] and other searches are *not* covered here. For some of the processes studied by CLEO and reviewed here similar or better limits were recently reported by BaBar and Belle experiments.

Our data sample was recorded with two configurations of the CLEO detector. The first third of the data was recorded with the CLEO II detector[6] which consisted of three cylindrical drift chambers placed in an axial solenoidal magnetic field of 1.5T, a CsI(Tl)-crystal electromagnetic calorimeter, a time-of-flight (TOF) plastic scintillator system and a muon system (proportional counters embedded at various depths in the steel absorber). Two thirds of the data were taken with the CLEO II.V configuration of the detector where the innermost drift chamber was replaced by a silicon vertex detector[7] (SVX) and the argon-ethane gas of the main drift chamber was changed to a helium-propane mixture. This upgrade led to improved resolutions in momentum and specific ionization energy loss (dE/dx) measurements.

The three-tier CLEO trigger system[8] complemented by the software filter for beam-gas rejection utilized the information from the two outer drift chambers, the TOF system and electromagnetic calorimeter. The response of the detector was modeled with a GEANT-based[9] Monte Carlo (MC) simulation program. The data and simulated samples were processed by the same event reconstruction program. Whenever possible the efficiencies were either calibrated or corrected for the difference between simulated and actual detector responses using direct measurements from independent data.

Most of the measurements reviewed here have been made by first measuring signal candidates yields and then, when necessary, subtracting background contributions. These "yields" were not always the numbers of events, often these were complicated weighted quantities optimized for signal-background separation. Simple "slice and dice" or counting method was employed in simpler analyses, more sophisticated techniques, such as maximum likelihood (ML) fitting, neural nets and optimal observable method were applied to more difficult cases. The resulting numbers were corrected for the overall efficiencies and then converted to the measured quantities using luminosities, branching fractions and, when necessary, theoretical input. Detailed description of these procedures can be found in references to CLEO publications. The reader can also find relevant theoretical references in these publications. Our results are based on 9.6 million $B\bar{B}$ events, 12.2 million $\tau^+\tau^-$ pairs and 9 fm^{-1} of e^+e^- statistics with SVX appropriate for precise D mesons measurements.

2 Bound on CP Asymmetry in $b \to s\gamma$ Decays

The theory[10] predicts very small $\mathcal{A}_{CP}$ asymmetry in inclusive rate for $b \to s\gamma$ where[2]

$$\mathcal{A}_{CP} = \frac{\Gamma(b \to s\gamma) - \Gamma(\bar{b} \to \bar{s}\gamma)}{\Gamma(b \to s\gamma) + \Gamma(\bar{b} \to \bar{s}\gamma)}. \tag{1}$$

In SM non-zero $\mathcal{A}_{CP}$ could arise from QCD radiative corrections and interference among processes whose amplitudes are driven by c_7 (QED penguin), c_2 (four-fermion) and c_8 (QCD

[2] Similar definitions of $\mathcal{A}_{CP}$ are used in all other analyses reviewed here.

penguin) Wilson coefficients in OEP expansion for effective weak Hamiltonian. This asymmetry is proportional to α_s and could be enhanced by some new processes that would modify effective theory. As with all other direct CP asymmetries discussed here, possible non-zero $\mathcal{A}_{CP}$ in $b \to s\gamma$ should vanish when summing over *all* B (or, separately, over all $\bar{B}$) decays is performed. This is required to conserve CPT and means equal lifetimes for a particle and corresponding antiparticle.

In our analyses[11, 12] the signature of $b \to s\gamma$ is high energy photon: 2.2 GeV $< E_\gamma <$ 2.7 GeV. To measure partial rates, flavor tagging is necessary. We achieved 89% and 90% correct b-flavor tagging by either using a high momentum lepton from the recoiling, non-signal B meson candidate, or, when lepton is not identified, with the help of pseudoreconstruction technique where charged kaon candidate was used for tagging. The effects of $B\bar{B}$ mixing were corrected for, substantial background from continuum processes (including initial state radiation (ISR)) was suppressed using π^0 and η vetoes and a combination of kinematic variables provided as the input to neural net trained using signal MC and background samples. The remaining background was subtracted using independent data sample recorded ≈ 60 MeV below $B\bar{B}$ threshold.

We do not tag strangeness in $b \to s\gamma$ (even when using pseudoreconstruction technique) because of three reasons: there is no kaon requirement in lepton flavor tagging method, our PID is far from being perfect in pseudoreconstruction method, and, finally, $K\bar{K}$ pairs could be popped up from vacuum after $b \to d\gamma$ quark-level transition thus faking the $b \to s\gamma$ signal. As the result our $b \to s\gamma$ and $b \to d\gamma$ efficiencies are almost the same. This is acceptable because the theory predicts that $b \to d\gamma$ contributes only $\approx 4\%$ to the inclusive radiative rate. To estimate the $b \to d\gamma$ contribution from data we performed searches[13, 14] for certain exclusive channels (such as $B \to \rho\gamma$ and $B \to D^{*0}\gamma$) that would be coming from B decays mediated via QED $b \to d\gamma$ penguin, W annihilation and W exchange and did not find these processes to have unexpectedly large branching fractions. However, our experimental limits on $b \to d\gamma$ are still approx. 10 times higher than what we would love to see as the experimental proof of $b \to d\gamma$ being small. Therefore, we *assume* $b \to s\gamma$ after subtracting all known contributions. As the result our measured $b \to s\gamma$ asymmetry is biased by possible small contribution from $b \to d\gamma$ that would give rise to $\mathcal{A}_{CP}$ asymmetry of opposite (to signal) sign.

We measure[11] $\mathcal{A}_{CP} = (-0.079 \pm 0.108 \pm 0.022)(1.0 \pm 0.03)$, where the first and second errors are statistical and additive systematic (same convention is used for all analyses reviewed here), and the 3% error is multiplicative systematic. Major contributions to systematics arise from mistag rate, continuum and $B\bar{B}$ background subtractions. Contribution from particle detection biases (matter-antimatter detection efficiency asymmetry) for kaons, pions and leptons is very small (less than 1%) as it is in all other analyses reported here. We also established a 90% confidence level (CL) interval $-0.27 < \mathcal{A}_{CP} < +0.10$ ruling out some extreme (though unspecified) non-SM predictions.

3 Exclusive QED Penguins and CP Asymmetry

Prompted by theoretical expectation of non-zero $\mathcal{A}_{CP}$ in inclusive $b \to s\gamma$ CLEO also measured this asymmetry in exclusive channels $B \to K^*(892)\gamma$. In this case flavor self-tagging was achieved using charged kaon or pion and it was assumed that $\mathcal{A}_{CP}$ is the same

for neutral and charged B mesons depending only on b quark flavor. We measured[14] $\mathcal{A}_{CP} = +0.01 \pm 0.06$, where only statistical error is shown (in this review we usually do not show systematics for statistics-limited measurements). To obtain this number we corrected for misidentification rate of $\approx 3.5\%$.

4 CP Asymmetry in Dileptons from $B\bar{B}$ Decays

Same-sign dileptons appear naturally in $\Upsilon(4S) \to B^0\bar{B}^0$ decays because of $B\bar{B}$ mixing. Similarly to neutral kaon decays, B mass and flavor eigenstates could be different with the former described in terms of the latter as $[(1+\epsilon_B)B^0 + (1-\epsilon_B)\bar{B}^0]/\sqrt{2(1+|\epsilon_B|^2)}$. This could give rise to CP violation (CPV) that would manifest itself in a non-zero value for

$$a_{ll} = \frac{N(l^+l^+) - N(l^-l^-)}{N(l^+l^+) + N(l^-l^-)} \approx \frac{4\mathcal{R}e(\epsilon_B)}{1+|\epsilon_B|^2}, \tag{2}$$

where index l stands for a lepton from semileptonic B decay.

Experimental challenges in this analysis include measuring dilution factor and the charge asymmetry in the fake probability from the data, continuum suppression and subtraction. Only high-momentum leptons are used in the measurement: 1.6 GeV/c $< p_l <$ 2.4 GeV/c. In this analysis[15] we measured $a_{ll} = (+0.013 \pm 0.050 \pm 0.005)(1.00 \pm 0.10)$. By combining this result with our previous (statistically independent) measurement[16] (where $B\bar{B}$ mixing was the main subject) we arrive at weighted average $\mathcal{R}e(\epsilon_B)/(1 + |\epsilon|^2) = +0.0035 \pm 0.0103 \pm 0.0015$. This is significant improvement in comparison to CDF result[17]: $+0.025 \pm 0.062 \pm 0.032$. Our sensitivity is similar to that of OPAL's result[18]: $+0.002 \pm 0.007 \pm 0.003$. In contrast to these two measurements our analysis is not affected by *possible* B_s contamination as these mesons can not be produced at energies available to us at $\Upsilon(4S)$.

5 Search for CP Violation in $B \to \psi^{(\prime)}K$ Decays

Possible SM contribution to direct CP asymmetry in $B^\pm \to \psi^{(\prime)}K^\pm$ decays is practically zero. However, some SM extensions would be able to explain non-zero $\mathcal{A}_{CP}$ (if observed). These are 2HDM extensions[19] where t quark plays a special role and masses of up- and down-type fermions are generated by different Higgs doublets. Presence of dileptons from $\psi^{(\prime)}$ decays allows a background-free analysis and we measured[20] $\mathcal{A}_{CP}(B^\pm \to \psi K^\pm) = +0.018 \pm 0.043 \pm 0.004$ and $\mathcal{A}_{CP}(B^\pm \to \psi' K^\pm) = +0.02 \pm 0.091 \pm 0.01$. These two channels are not combined together because rescattering that would give rise to FSI and CP-conserving strong phase necessary for observing the effects of (CP non-conserving) new physics is channel-dependent.

6 CP Asymmetries in Charmless Hadronic B Decays

We also measured[21] $\mathcal{A}_{CP}$ for five two-body charmless hadronic B decays. The theory[22] predicts $\mathcal{A}_{CP} < 0.1$ for these decays assuming factorization and no soft FSI. The non-zero SM $\mathcal{A}_{CP}$ arises from the interference between tree $b \to u$ and penguin $b \to s$ transitions.

There are indications that their amplitudes in studied B decays are comparable, therefore (assuming large strong phase) $\mathcal{A}_{CP}$ might be observable with existing data. Once again, if there is new physics contribution in the quark-level transitions for decays of heavy flavors and FSI (or rescattering) is large, $\mathcal{A}_{CP}$ could be much larger. Using self-tagging we found $\mathcal{A}_{CP}(B \to K^{\pm}\pi^{\mp}) = -0.04 \pm 0.16$, $\mathcal{A}_{CP}(B \to K^{\pm}\pi^{0}) = -0.29 \pm 0.23$, $\mathcal{A}_{CP}(B \to K_s^0\pi^{\pm}) = +0.18 \pm 0.24$, $\mathcal{A}_{CP}(B \to K^{\pm}\eta') = +0.03 \pm 0.12$ and $\mathcal{A}_{CP}(B \to \omega\pi^{\pm}) = -0.34 \pm 0.25$, where only statistical errors are shown. The interpretation of these results, consistent with the SM predictions, would be subject to FSI contribution uncertainties even if some $\mathcal{A}_{CP}$ were established to be non-zero. As in many other analyses where SM CPV *is* allowed, it is strong interaction that would make (possible) new physics effects to realize at low energies, while quantifying its role in extracting parameters associated with these effects could be very difficult.

7 Search for CP Violation in τ Decays

In contrast to charmless B decays, no SM CP violation is possible in τ sector and our previous search[23] did not find any in our $\tau^{\pm} \to K_s^0\pi^{\pm}\nu$ data. Since than we realized that a more powerful search is possible using the optimal observable method[24]. This method is based on presenting the data in the form most sensitive to a particular SM extension. We did not find CP violation in our new $\tau^{\pm} \to \pi^{\pm}\pi^{0}\nu$ analysis[25] and, analyzing our data using a particular 3HDM SM extension[26] established a 90% CL interval on the parameter Λ that describes convoluted complex combination of this model's coupling constants: $-0.046 < \mathcal{I}m(\Lambda) < 0.022$. In this model τ can also decay via charged Higgs boson. We also reanalyzed $\tau^{\pm} \to K_s^0\pi^{\pm}\nu$ data in the same spirit and measured[27] $-0.155 < \mathcal{I}m(\Lambda) < 0.047$ 90% CL interval (preliminary result). Our new results are obtained using conservative form-factor model for hadronic part of studied τ decays. Namely, we experimented with three models for form factors and chose the one that generated smallest strong phase (thus reducing our potential sensitivity to hidden new physics).

8 CP Violation in D Decays to Pseudoscalar Pairs

We measured $\mathcal{A}_{CP}$ for five D^0 decay channels: $\mathcal{A}_{CP}(D \to K^+K^-) = +0.0005 \pm 0.0218 \pm 0.0084$ and $\mathcal{A}_{CP}(D \to \pi^+\pi^-) = +0.020 \pm 0.032 \pm 0.008$ (preliminary results[28]), $\mathcal{A}_{CP}(D \to K_s^0\pi^0) = +0.001 \pm 0.013$, $\mathcal{A}_{CP}(D \to \pi^0\pi^0) = +0.001 \pm 0.048$ and $\mathcal{A}_{CP}(D \to K_s^0K_s^0) = -0.23 \pm 0.19$, where only statistical errors are shown for the last three channels[29]. In these analyses d flavor was tagged by the charge of pion from two-body decay $D^{*+} \to \pi^+D^0$ (and charge-conjugate). Assuming that D^* decay is CP-conserving, to measure $\mathcal{A}_{CP}$ for D mesons we actually measure the numbers of D^{*+} (D^{*-}) decays followed by the D^0 ($\bar{D^0}$) decay. Possible non-zero $\mathcal{A}_{CP}$ would be manifestation of direct CP violation which is usually predicted to be small in SM, of the order of 0.1% in the charmed mesons sector[30]. However there are indications that large FSI effects are present in D decays and this would make them an excellent place to search for CP violation with more data expected at CLEO-c[31].

9 New Fits to D^0 Proper Time and y Measurement

The first two $\mathcal{A}_{CP}$ measurements for charmed mesons described above are actually a by-product of the new analysis of D^0 proper time measured with CLEO II.V SVX by reconstructing the displaced vertices of the D^0 mesons decaying in flight. Proper time measurements provide us with information on $D\bar{D}$ mixing that can proceed via on-shell and off-shell intermediate states. In a widely accepted framework the amplitude for former (latter) contribution is $-iy$ (x) in units of $\Gamma_{D^0}/2$. The signatures of new physics include $|x| >> |y|$ and possible large $|\mathcal{I}m(x)/x|$ causing CP violating interference between x and y or between x and direct decay amplitudes to the same final state. SM x contribution to $D\bar{D}$ mixing is strongly Cabibbo-suppressed: $|x| \approx \tan^2\theta_C \approx 5\%$ and this is reduced further down to $|x| \approx 10^{-6}$–10^{-2} by GIM cancelation where large uncertainty is due to strong interaction effects. In the limit of no CP violation in D^0 decays, one can measure y by comparing distributions of decay distances (*i.e.* by measuring proper times) for samples of D^0 mesons decaying to CP eigenstates and to the states of mixed CP. We measured[28] proper times for D^0 decays to K^+K^-, $\pi^+\pi^-$ and $K^+\pi^-$ final states and obtained preliminary result $y = -0.011 \pm 0.025 \pm 0.014$ which is consistent with zero. This is in agreement with our previous measurement[32] and recent FOCUS results[33].

10 First Measurement of $D^0 \to K^+\pi^-\pi^0$ Rate

Charmed meson initially tagged as D^0 can be observed in a "wrong-sign" (WS) final state, such as $K^+\pi^-\pi^0$ as the result of direct doubly Cabibbo-suppressed decay (DCSD) or via a "right-sign" (RS) $\bar{D}^0$ decay after mixing. In this analysis[34] we measure time-integrated ratio

$$R(K\pi\pi) = \frac{\Gamma(D^0 \to K^+\pi^-\pi^0)}{\Gamma(\bar{D}^0 \to K^+\pi^-\pi^0)} = R_D(K\pi\pi) + \sqrt{R_D(K\pi\pi)}y' + \frac{x'^2 + y'^2}{2}, \tag{3}$$

where $R_D(K\pi\pi)$ is the relative rate of DCSD for this channel, $x' = x\cos\delta + y\sin\delta$, $y' = y\cos\delta - x\sin\delta$ and δ is a possible strong phase between direct and mixing-induced WS amplitudes.

We measure $R(K\pi\pi)$ from the two-dimensional ML fit in $m(K\pi\pi)$ *vs.* $Q = M_{D^*} - M_{K\pi\pi} - m_\pi$ and use the results to establish the WS decay. From our binned ML fit we measure $R(K\pi\pi) = 0.0043^{+0.0011}_{-0.0010} \pm 0.0007$. With more statistics we could have made a time-dependent fit to extract x', y' and $R_D(K\pi\pi)$ simultaneously (although with correlations), however, with our data (observing 38 ± 9 WS $K\pi\pi$ events) we can only measure $R_D(K\pi\pi) = (1.7 \pm 0.4 \pm 0.3) \times \tan^4\theta_C$ assuming no mixing. If, instead, we assumed $\delta(K\pi\pi) = \delta(K\pi)$ (unfounded), $y' = 0$ and $|x'| = 0.028$ (using 95% CL upper limit from our previous measurement[32]), these changes would have had very small effect on our $R_D(K\pi\pi)$ result.

11 New Results on FCNC Decays $B \to K^{(*)}l^+l^-$

Processes mediated by (effective, in SM) Flavor Changing Neutral Currents (FCNC) are among the best candidates to search for new physics in B decays. Field-theoretical description of FCNC decays contains loop and box diagrams and this would make it easy to explain

deviations from SM (if observed) by introducing much heavier non-SM particles that would affect the total rate and modify differential distributions for these decays.

Background suppression is one of the challenges present in this analysis. In addition to continuum (includes ISR) there are dileptons from $\psi^{(\prime)}$ and $B\bar{B}$ decays. Almost all background-suppression variables and methods developed on CLEO are combined to achieve the best possible sensitivity in our blind analysis that uses 12 e^+e^- and $\mu^+\mu^-$ exclusive channels. To make $\psi^{(\prime)}$ suppression efficient we correct their four momenta to include internal and external bremsstrahlung photons (when recovered) and apply wide vetoes on invariant masses. For example, in e^+e^- channels we veto candidates with (corrected, when applicable) dielectron invariant masses in the range between 2.80 and 3.23 GeV. To suppress $B\bar{B}$ dileptons we employ missing mass technique developed on CLEO for neutrino "detection". Careful studies of e and μ reconstruction efficiencies using data have been carried over the past two years and this is the reason why our new FCNC results became available only recently. To suppress virtual $K^*\gamma$ contribution we select events with dilepton invariant mass $m_{ll} > 0.5$ GeV/c^2 in the K^* analyses. Continuum background is suppressed using Fisher discriminant that combines all available kinematic information about each B candidate and the event as a whole. In each channel selection criteria were optimized for the discovery and best upper limit with the average used in the actual analysis. This gave us overall (weighted) efficiency of 54.8%.

Summing over all channels we counted the number of observed events in the signal box of beam-constrained B mass *vs.* ΔE, the difference between the beam energy and that of a candidate and found 7 events while our data-based estimates of background contribution is 5.8±0.8. As the result we achieved excellent sensitivity and measured[35] 90% CL (Bayesian) upper limits for B branching fractions

$$\begin{gathered}
\mathcal{B}(B \to K l^+ l^-) < 1.7 \times 10^{-6}, \\
\mathcal{B}(B \to K^*(892) l^+ l^-)_{m_{ll} > 0.5 \text{ GeV}} < 3.2 \times 10^{-6} \text{ and} \\
[0.65\mathcal{B}(B \to K l^+ l^-) + 0.35\mathcal{B}(B \to K^*(892) l^+ l^-)_{m_{ll} > 0.5 \text{ GeV}}] < 1.5 \times 10^{-6},
\end{gathered}$$

where the latter efficiency-weighted limit is just 50% above the SM prediction[36] with almost no model dependence in the efficiency. We estimate that to become actually sensitive to new physics contribution in these decays data samples of the order of 500 fb^{-1} might be necessary.

12 Future τ-charm Factory at Cornell

At future CLEO-c experiment[31] we plan to use the existing CLEO III apparatus with silicon vertex detector replaced by a compact low-mass inner drift chamber. This detector will collect data at the J/ψ and $e^+e^- \to D\bar{D}$ threshold energies with initial CESR-c instantaneous luminosity around 3–5 $\times 10^{32}$ cm^{-2} s^{-1}. CLEO-c will operate with reduced magnetic field (down to 1.0 Tesla from 1.5 Tesla at present, this only requires turning a knob) in the main part of the detector. At CLEO-c we plan to collect samples of 1.5 million $D_s\bar{D}_s$ pairs, 30 million $D\bar{D}$ pairs and 1 billion J/ψ decays. These exceed the MARK-III statistics by the factors of 480, 310 and 170, respectively.

An important element of our CLEO-c program is to measure the D mesons coupling constants that are important for testing Lattice QCD (LQCD) predictions. If these predictions are confirmed by the measurements, there would be a degree of confidence in

LQCD calculations for f_B. Then the theory could be used to reduce hadronic uncertainties in future measurements of CKM matrix elements at B-factories and Fermilab. Reducing hadronic uncertainties in CKM measurements should help to "over-constrain" the unitarity triangles thus possibly leading to hints of new physics contribution to the decays of heavy mesons. The measurements of $f_{D_{(s)}}$ coupling constants will be done at CLEO-c by precisely measuring the rates for the $D \to l\bar{\nu}$ and $D_s \to l\bar{\nu}$ decays. The main advantage of CLEO-c will be the ability to "tag" the signal D meson decaying leptonically by fully reconstructing the recoiling D and by detecting a lepton from signal D decay. Applying kinematic constraints will help to bring the neutrino "detection" technique to a qualitatively better level than is possible on CLEO at present in B decays. According to our estimates we should be able to achieve the 2% precision in the measurements of f_D and f_{D_s}. At present these are known with 35% and 100% errors, respectively. We also plan to measure many other D branching fractions with much better precision than these are known at present. Knowledge of these branching fractions, such as $\mathcal{B}(D \to K\pi)$ is important for normalizing measurements at higher energies.

In our future $D\bar{D}$ mixing and CP asymmetries studies we should benefit from the fact that D and $\bar{D}$ at CLEO-c will be produced in a coherent quantum state. This is crucial for direct CP searches we plan to undertake. The key point is that when a $D\bar{D}$ pair is produced in a C-odd initial state from e^+e^- annihilation, a final state with two CP eigenstates of the same CP eigenvalue would be an unambiguous manifestation of direct CP violation. As the result of our CLEO-c program we expect to achieve the precision of better than 1% in the measurements of $D\bar{D}$ mixing and $\mathcal{A}_{CP}$ asymmetry parameter for D mesons.

The decays of J/ψ will be studied at CLEO-c with an unprecedented precision and in much detail. Our main emphasis here would be on studying radiative decays of J/ψ to light mesons as these provide a glue-rich experimental laboratory where new states of hadronic matter, generally referred to as glueballs and exotics could be finally unambiguously discovered and studied. With one billion J/ψ decays we will be able to perform partial wave analyses and global fits for many mysterious decays of J/ψ (such as $J/\psi \to \gamma f_j(2220)$) presumably observed previously, however, with poor statistics.

The measurements of R, the total hadronic cross section in e^+e^- annihilation in a wide range of e^+e^- invariant masses ($\sqrt{S}$) proposed at CLEO-c is an integral part of global efforts in heavy flavor physics. These measurements will help to reduce uncertainties associated with extracting new physics effects from existing and future data at higher energies experiments. By measuring $\mathcal{R}$ in a wide range of $\sqrt{S}$ we should be able to further constrain the mass of the (minimal) SM Higgs. In this case, the analysis of $\mathcal{R}$ would result in the measurement of running α(electromagnetic) that should allow to put more restrictive limits on the mass of SM Higgs if it is not yet discovered by the time CLEO-c data is available. Finally, precise scan of $\mathcal{R}$ might give information about vector hybrids, *i.e.* hadrons consisting of $q\bar{q}g$ whose existence is predicted by LQCD calculations. The latter project's feasibility would depend on the magnitudes of e^+e^- partial widths of such hypothetic resonances. We expect to achieve the 2% precision per point in the measurements of R at CLEO-c in the invariant mass region between 3 and 5 GeV. CESR-c will have the ability to run with a single beam energy of up to 5.6 GeV thus opening the prospects to do the measurements at even higher $\sqrt{S}$. As relevant for R measurements we are especially interested in $\sqrt{S}$ region above J/ψ and below Υ resonances. CESR-c and CLEO-c is a three-year program that is expected to start in the end of 2002.

13 Conclusions and Acknowledgments

CLEO has searched for a variety of CP asymmetries, "wrong-sign" D^0 decays and B decays mediated by FCNC transitions with the purpose to probe the non-SM physics. No evidence of such contribution was found. More precise measurements are starting coming from other B physics experiments, better limits on or the discovery of $D\bar{D}$ mixing and CP violation in D decays should be expected at these facilities and at future τ-charm factory at Cornell (CLEO-c and CESR-c).

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